



**National Pollutant Inventory**

# **Emission Estimation Technique Manual**

**for**

## **Ferroalloy Production**

*First published in November 1999*

---

**EMISSION ESTIMATION TECHNIQUES  
FOR  
FERROALLOY PRODUCTION**

**TABLE OF CONTENTS**

<b>1.0</b>	<b>INTRODUCTION</b>	<b>1</b>
	1.1 Manual Structure	2
	1.2 Manual Application	2
<b>2.0</b>	<b>PROCESS DESCRIPTION</b>	<b>4</b>
<b>3.0</b>	<b>EMISSION SOURCES</b>	<b>5</b>
	3.1 Reporting Thresholds	5
	3.1.1 Category 1	5
	3.1.2 Category 2	6
	3.1.3 Category 3	7
	3.2 Emissions to Air	7
	3.2.1 Emission Factors for Open Submerged Arc Silicomanganese Furnaces	12
	3.2.2 Speciating Total Suspended Particulate Emissions	12
	3.3 Emissions to Water	13
	3.4 Emissions to Land	14
<b>4.0</b>	<b>GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS</b>	<b>16</b>
<b>5.0</b>	<b>REFERENCES</b>	<b>17</b>
	<b>APPENDIX A - EMISSION ESTIMATION TECHNIQUES</b>	<b>18</b>
	A.1 Direct Measurement	19
	A.1.1 Sampling Data	19
	A.1.2 Continuous Emission Monitoring System (CEMS) Data	22
	A.2 Using Mass Balance	24
	A.3 Engineering Calculations	26
	A.3.1 Fuel Analysis	26
	A.4 Emission Factors	27
	<b>APPENDIX B - EMISSION ESTIMATION TECHNIQUES: ACCEPTABLE RELIABILITY AND UNCERTAINTY</b>	<b>29</b>
	B.1 Direct Measurement	29
	B.2 Mass Balance	29
	B.3 Engineering Calculations	30
	B.4 Emission Factors	30
	<b>APPENDIX C - LIST OF VARIABLES AND SYMBOLS</b>	<b>31</b>

---

## FERROALLOY PRODUCTION

### LIST OF TABLES AND EXAMPLES

<b>Table 1 - Substances that will Trigger Category 1 Reporting Thresholds</b>	<b>5</b>
<b>2 - Energy Consumption at TEMCO</b>	<b>6</b>
<b>3 - Category 2 Substances That Trigger Reporting</b>	<b>7</b>
<b>4 - Sources of Air Emissions from Ferroalloy Manufacturing Processes</b>	<b>8</b>
<b>5 - Emission Factors for Submerged Arc SiMn Ferroalloy Furnaces</b>	<b>12</b>
<b>6 - Weight Percentage Composition of Silicomanganese Fume from a Semi Open Submerged Arc Furnace</b>	<b>13</b>
<b>7 - Stack Sample Test Results</b>	<b>20</b>
<b>8 - Example CEMS Output for a Hypothetical Furnace Firing Waste Fuel Oil</b>	<b>22</b>
<b>Example 1 - Category 1 Threshold Calculations</b>	<b>6</b>
<b>2 - Speciating TSP Emissions</b>	<b>13</b>
<b>3 - Emissions to Water Calculations</b>	<b>14</b>
<b>4 - Using Stack Sampling Data</b>	<b>20</b>
<b>5 - Calculating Moisture Percentage</b>	<b>21</b>
<b>6 - Using CEMS Data</b>	<b>24</b>
<b>7 - Using Fuel Analysis Data</b>	<b>27</b>

---

## 1.0 Introduction

The purpose of all Emission Estimation Technique (EET) Manuals in this series is to assist Australian manufacturing, industrial and service facilities to report emissions of listed substances to the National Pollutant Inventory (NPI). This Manual describes the procedures and recommended approaches for estimating emissions from facilities engaged in ferroalloy production.

The ferroalloy production activities covered in this Manual apply to facilities primarily engaged in the manufacture of ferroalloy materials. At the time of developing this Manual (May-August 1999), the only ferroalloys produced in Australia are ferromanganese and silicomanganese and the only producer of ferroalloys is TEMCO in Tasmania.

EET MANUAL:           Ferroalloy Production

HANDBOOK:           Ferroalloy Production

ANZSIC CODE:        2711 and all codes in the 271 ANZSIC code group.

The Manual does not cover Basic Iron and Steel Manufacturing, Steel Casting or Steel Rolling Mill Operations (which are also listed under ANZSIC Code 2711). These activities have been included in the *Emission Estimation Technique Manual for Iron & Steel Production*.

Pacific Air & Environment Pty Ltd drafted this Manual on behalf of Environment Australia. It has been developed through a process of national consultation involving State and Territory environmental authorities. Particular thanks are due to TEMCO for their comments, advice and information.

---

## 1.1 Manual Structure

This Manual is structured as follows:

- **Section 2** provides a brief introduction to the ferroalloy manufacturing process.
- **Section 3.1** summarises the NPI-listed substances that are triggered, or likely to be triggered, for the ferroalloy industry. Category 1, 2 and 3 substances are discussed in **Sections 3.1.1, 3.1.2 and 3.1.3** respectively. **Sections 3.2, 3.3 and 3.4** detail the expected emissions to air, water and land respectively from the ferroalloy manufacturing process. These sections also detail the sources of these emissions and where emission estimation techniques for each of these sources are to be found.
- **Section 4** provides a glossary of technical terms and abbreviations used in this Manual.
- **Section 5** provides a list of references used in the development of this Manual.
- **Appendix A** provides an overview of the four general types of emission estimation techniques: sampling or direct measurement; mass balance; engineering calculations and emission factors, as well as example calculations to illustrate their use. Reference to relevant sections of this appendix is recommended in understanding the application of these techniques with particular respect to the ferroalloy industry.
- **Appendix B** provides a discussion of the reliability and uncertainty associated with each of the techniques presented in **Appendix A**.
- **Appendix C** provides a list of variables and symbols used throughout this Manual.

## 1.2 Manual Application

### *Context and use of this Manual*

This NPI Manual provides a 'how to' guide for the application of various methods to estimate emissions as required by the NPI. It is recognised that the data that is generated in this process will have varying degrees of accuracy with respect to the actual emissions from ferroalloy processing facilities. In some cases, there will necessarily be a large potential error due to inherent assumptions in the various emissions estimation techniques (EETs) and/or a lack of available information of chemical processes.

*EETs should be considered as 'points of reference'*

The EETs and generic emission factors presented in this Manual should be seen as 'points of reference' for guidance purposes only. Each has associated error bands that are potentially quite large. **Appendix B** discusses the general reliability associated with the various methods. The potential errors associated with the different EET options should be considered on a case-by-case basis as to their suitability for a particular facility. Facilities may use EETs that are not outlined in this document. They must, however, seek the consent of their relevant environmental authority to determine whether any 'in house' EETs are suitable for meeting their NPI reporting requirements.

---

*Hierarchical approach recommended in applying EETs*

This Manual presents a number of different EETs, each of which could be applied to the estimation of NPI substances. The range of available methods should be viewed as a hierarchy of available techniques in terms of the error associated with the estimate. Each substance needs to be considered in terms of the level of error that is acceptable or appropriate with the use of the various estimation techniques. Also, the availability of pre-existing data and the effort required to decrease the error associated with the estimate will need to be considered. For example, if emissions of a substance are clearly very small, no matter which EET is applied, then there would be little gained by applying an EET which required significant additional sampling.

The steps in meeting the reporting requirements of the NPI can be summarised as follows:

*Category 1 and 1a Substances:*

Identify which reportable NPI substances are used (or handled by way of their incidental presence in ore or materials, or exceeds the bulk storage capacity for 1a), and determine whether the amounts used or handled are above the 'threshold' values and therefore trigger reporting requirements. See Section 3.1.1 of this Manual for guidance on which Category 1 substances are likely to require reporting in the ferroalloy production industry.

*Category 2a and 2b Substances:*

Determine the amount and rate of fuel (or waste) burnt each year, the annual power consumption and the maximum potential power consumption, and assess whether the threshold limits are exceeded. See Section 3.1.2 of this Manual for a discussion of which Category 2 substances are likely to be triggered in the ferroalloy industry.

*Category 3 Substances:*

Determine the annual emissions to water and assess whether the threshold limits are exceeded. It appears that this NPI Category will not be relevant to ferroalloy production.

*Those substances above the threshold values:*

Examine the available range of EETs and determine emission estimates using the most appropriate EET.

Generally, it will be appropriate to consider various EETs as alternative options whose suitability should be evaluated in terms of:

- the associated reliability or error bands; and
- the cost/benefit of using a more reliable method.

The accuracy of particular EETs is discussed in **Appendix B**.

*NPI emissions in the environmental context*

It should be noted that the NPI reporting process generates emission estimates only. It does not attempt to relate emissions to potential environmental impacts, bioavailability of emissions or natural background levels.

---

## 2.0 Process Description

Ferromanganese and silicomanganese are produced by smelting manganese ore, quartzite, iron ore(s), dolomite, limestone, (fluxes) and coke and coal (reductants) in submerged arc furnaces. The raw materials are fed by front end loaders to dump hoppers and conveyors to be crushed and screened. Measured quantities of the raw materials are fed into the furnaces by gravity. Alloy tapped from the furnaces is fed to casting machines or to metal bays for layer casting. The slag is poured into ladles and transported to a slag dump station where it is cast and processed.

Furnace off gas is scrubbed to remove particulate material and condensate. The gas, consisting largely of carbon monoxide, is fired in an on-site power station to produce electricity.

A down draught sintering machine produces high quality manganese sinter from manganese ore fines and coke breeze for use as furnace feed.

The approximate production capacity for Australian and export markets is:

- 110 000 tonnes per annum for ferromanganese;
- 110 000 tonnes per annum for silicomanganese; and
- 303 000 tonnes per annum for sinter.

---

### 3.0 Emission Sources

#### 3.1 Reporting Thresholds

##### 3.1.1 Category 1

The NPI-listed substances that are likely to trigger Category 1 reporting thresholds in the ferroalloy production industry are listed in Table 1. These substances are present in raw materials and products in concentrations such that the 10 tonne per year threshold will be exceeded.

The usage of each of the substances listed as Category 1 and 1a under the NPI must be estimated to determine whether the 10 tonnes (or 25 tonnes for VOCs) reporting threshold is exceeded. If the threshold is exceeded, emissions of these Category 1 and 1a substances must be reported for all operations/processes relating to the facility, even if the actual emissions of the substances are very low or zero. Usage is defined as meaning the handling, manufacture, import, processing, coincidental production or other uses of the substances.

**Table 1 - Substances that will Trigger Category 1 Reporting Thresholds**

Category 1 Substances	
Arsenic & compounds	Fluoride compounds
Cadmium & compounds	Lead & compounds
Cobalt & compounds	Manganese & compounds
Copper & compounds	Nickel & compounds
	Zinc & compounds

Insufficient information is presently available to enable a definite assessment to be made as to whether Category 1 reporting thresholds will be triggered for chromium (III) or chromium (VI). To determine whether or not the 10 tonnes per annum threshold would be exceeded, the calculation process outlined in Example 1 below needs to be followed.



### Example 1 - Category 1 Threshold Calculations

A manganese ore analysis supplied by TEMCO shows that 20µg of chromium per g of ore (equivalent to 20 g per tonne of ore) is present. No information is presently available on whether the chromium is in the form of chromium (III) or chromium (VI). The facility uses approximately 150 000 tonnes of manganese ore per year. Is the Category 1 threshold for chromium exceeded?

In furnace No. 5, the total chromium input from the manganese ore is:

$$\frac{20 \text{ g Chromium}}{\text{t Mn Ore}} * \frac{150\,000 \text{ t Mn Ore}}{\text{yr}} = \frac{3\,000\,000 \text{ g Chromium}}{\text{yr}} = \frac{3.0 \text{ t Chromium}}{\text{yr}}$$

This is significantly lower than the Category 1 reporting threshold of 10 tonnes per year. Therefore, even if the chromium in the ore is present entirely in the form of either chromium (III) or chromium (VI), the Category 1 threshold is unlikely to be triggered. However, it should be noted that this analysis has only been performed for the manganese ore that is input into the process. Silica ore, iron ore, coke, coal and dolomite may also contain chromium. Therefore, each of these materials should be analysed for chromium in a similar manner, to determine whether the Category 1 reporting threshold for either chromium (III) or chromium (VI) is exceeded for the facility.

### 3.1.2 Category 2

Category 2 thresholds are based on energy or fuel use. TEMCO's energy use for the April to June 1999 quarter is summarised in Table 2. Based on these data, the Category 2a threshold is exceeded by annual LPG usage alone. The Category 2b threshold of 60 000 MWh per year is also exceeded on target figures. Therefore, emissions of all Category 2 substances need to be reported.

Table 2 - Energy Consumption at TEMCO<sup>a</sup>

	April to June 1999	Yearly <sup>d</sup>
Fuels Used		
LPG (kg)	216 490	865 960
Distillate <sup>b</sup> (L)	145 764	583 056
Petrol <sup>c</sup>	No data	No Data
Own Energy Produced (MWh)	21 727	86 908

<sup>a</sup> Information supplied by TEMCO.

<sup>b</sup> It is recommended that the supplier of distillate be requested to provide the density of the distillate used at the facility. Alternatively, a density of 876 kg/m<sup>3</sup> may be assumed (Perry and Green, 1997).

<sup>c</sup> Petrol is used at the facility, but no quarterly data is available.

<sup>d</sup> Multiplying data for April to June by four.

The NPI-listed Category 2a and 2b substances are presented in Table 3. As shown in the table, a number of these substances also trigger Category 1 reporting requirements (see Table 1 of this Manual).

**Table 3 - Category 2 Substances That Trigger Reporting**

Category 2a Substances	Category 2b Substances
Carbon Monoxide Fluoride Compounds Hydrochloric Acid Oxides of Nitrogen Particulate Matter (PM <sub>10</sub> ) Polycyclic Aromatic Hydrocarbons Sulfur Dioxide Total Volatile Organic Compounds	Arsenic & compounds Beryllium & compounds Cadmium & compounds Chromium (III) compounds Chromium (VI) compounds Copper and compounds Lead & compounds Magnesium Oxide Fume Manganese & compounds Mercury & compounds Nickel & compounds Nickel Carbonyl Nickel Disulfide Polychlorinated Dioxins and Furans

**3.1.3 Category 3**

From information provided by TEMCO it is extremely unlikely that reporting on Category 3 substances would be required.

**3.2 Emissions to Air**

Table 4 is a summary of NPI-listed substances that may be emitted to air from process and ancillary operations in ferroalloy production.

**Table 4 - Sources of Air Emissions from Ferroalloy Manufacturing Processes**

Activity	Air Emissions	Sources of Information on Emission Estimation Techniques
<p><b>Materials Receipt and Handling</b></p> <ul style="list-style-type: none"> <li>• Bulldozers</li> <li>• Trucks</li> <li>• Wheel generated dust</li> <li>• Scrapers</li> <li>• Truck loading/unloading of stockpiles</li> <li>• Shaping of stockpiles by excavators</li> <li>• Front end loader operation</li> <li>• Delivery to dump hopper</li> <li>• Conveyer to screens, crusher and storage bins</li> <li>• Miscellaneous transfer points</li> <li>• Wind erosion from stockpiles</li> <li>• General handling</li> <li>• Alloy crushing and screening</li> </ul>	<ul style="list-style-type: none"> <li>• Arsenic &amp; Compounds</li> <li>• Cadmium &amp; compounds</li> <li>• Cobalt &amp; compounds</li> <li>• Copper &amp; compounds</li> <li>• Lead &amp; compounds</li> <li>• Manganese &amp; compounds</li> <li>• Nickel &amp; compounds</li> <li>• Zinc &amp; compounds</li> <li>• Beryllium &amp; compounds</li> <li>• Chromium (III) compounds</li> <li>• Chromium (VI) compounds</li> <li>• Mercury &amp; compounds</li> <li>• Particulate Matter (PM<sub>10</sub>)</li> </ul>	<p>All of these activities are covered by the <i>Emission Estimation Technique Manual for Mining</i>.</p> <p>Note that most of the products handled by TEMCO have a high moisture content and/or are large in size. Therefore, emissions of PM<sub>10</sub> may be lower than those predicted using the emission estimation technique presented in the <i>EET Manual for Mining</i>. In the absence of site-specific information the techniques presented in the <i>EET Manual for Mining</i> should be adopted as a starting point for emissions estimation. However, it should be recognised that some of these emission estimation techniques may not be directly applicable to moist ore materials or to coarse materials such as quartzite, dolomite and limestone.</p> <p>Note that there are also motor vehicle exhaust emissions associated with materials receipt and handling. The <i>EET Manual for Mining</i> provides estimation techniques that can be used for characterising these emissions.</p>

**Table 4 - Sources of Air Emissions from Ferroalloy Manufacturing Processes (cont')**

Activity	Air Emissions	Sources of Information on Emission Estimation Techniques
<p><b>Sinter Plant</b></p> <ul style="list-style-type: none"> <li>• Conveyers</li> <li>• Electrostatic Precipitator (ESP)</li> <li>• Multiclone</li> </ul>	<ul style="list-style-type: none"> <li>• PM<sub>10</sub></li> <li>• Arsenic &amp; Compounds</li> <li>• Cadmium &amp; compounds</li> <li>• Cobalt &amp; compounds</li> <li>• Copper &amp; compounds</li> <li>• Fluoride compounds</li> <li>• Lead &amp; compounds</li> <li>• Manganese &amp; compounds</li> <li>• Nickel &amp; compounds</li> <li>• Zinc &amp; compounds</li> <li>• Beryllium &amp; compounds</li> <li>• Chromium (III) compounds</li> <li>• Chromium (VI) compounds</li> <li>• Mercury &amp; compounds</li> <li>• Carbon monoxide</li> <li>• Sulfur Dioxide</li> <li>• Oxides of Nitrogen</li> <li>• Polycyclic Aromatic Hydrocarbons</li> <li>• Polychlorinated Dioxins and Furans</li> </ul>	<p>Dust from charge points of conveyers is collected in a baghouse. Monitoring data exists for TSP that can be used as a basis for characterising emissions of PM<sub>10</sub>. For the purposes of NPI reporting, it can be assumed that most of the collected and emitted material will be sinter dust (ie. Mn<sub>3</sub>O<sub>4</sub>).</p> <p>TEMCO has conducted monitoring for TSP, oxides of sulfur, oxides of nitrogen, dioxins, furans and PAHs for the ESP. In addition, there is data available on the size distribution of TSP and the various metals present in the collected dust. It is considered that this information will be sufficient to characterise emissions for the purposes of NPI reporting. See <b>Appendix A.1</b> for a discussion on how these data may be used for emissions estimation.</p> <p>TEMCO has conducted monitoring for emissions of TSP, oxides of sulfur, oxides of nitrogen, dioxins, furans and PAHs for the multicyclone. In addition, there is data available on the size distribution of TSP and the various metals present in the collected dust. It is considered that this information will be sufficient to characterise emissions for the purposes of NPI reporting.</p>

**Table 4 - Sources of Air Emissions from Ferroalloy Manufacturing Processes (cont')**

Activity	Air Emissions	Sources of Information on Emission Estimation Techniques
<p><b>Closed Submerged Arc Furnaces</b> (Furnaces No. 1, 2 &amp; 3 at TEMCO)</p> <p>Furnace gases (from inside the furnace) are collected and routed to either the energy recovery unit (ERU) or the flare. External (fugitive) gases are also emitted.</p>	<ul style="list-style-type: none"> <li>• PM<sub>10</sub></li> <li>• Arsenic &amp; Compounds</li> <li>• Cadmium &amp; compounds</li> <li>• Cobalt &amp; compounds</li> <li>• Copper &amp; compounds</li> <li>• Fluoride compounds</li> <li>• Lead &amp; compounds</li> <li>• Manganese &amp; compounds</li> <li>• Nickel &amp; compounds</li> <li>• Zinc &amp; compounds</li> <li>• Beryllium &amp; compounds</li> <li>• Chromium (III) compounds</li> <li>• Chromium (VI) compounds</li> <li>• Mercury &amp; compounds</li> <li>• Carbon monoxide</li> <li>• Sulfur Dioxide</li> <li>• Oxides of Nitrogen</li> <li>• Polycyclic Aromatic Hydrocarbons</li> <li>• Polychlorinated Dioxins and Furans</li> </ul>	<p>ERU: TEMCO has conducted monitoring for TSP and characterised the metals in the emitted particulate matter. It is considered that this information will be sufficient to characterise emissions for the purposes of NPI reporting. See Appendix A.1 for a discussion of how these data may be used for emissions estimation. The <i>Emission Estimation Technique Manual for Combustion in Boilers</i> Manual provides default emission factors for substances for which monitoring data may not presently be available. It is recognised that these emission factors may not provide a completely accurate characterisation of emissions but they do provide a starting point for emissions estimation.</p> <p>Flare: In the absence of site-specific information, emission factors for CO Boilers (in Section 4.2 of the <i>Emission Estimation Technique Manual for Petroleum Refining</i>) may be used as a starting point for the estimation of flare emissions. It is recognised that emissions from the flare may not be directly comparable to those in petroleum refining. However, the emission factors in the <i>Emission Estimation Technique Manual for Petroleum Refining</i> do at least provide a starting point for emission estimation.</p>

**Table 4 - Sources of Air Emissions from Ferroalloy Manufacturing Processes (cont')**

Activity	Air Emissions		Sources of Information on Emission Estimation Techniques
<p><b>Closed Submerged Arc Furnaces continued</b> (Furnaces No. 1, 2 &amp; 3 at TEMCO)</p> <ul style="list-style-type: none"> <li>• Tapping Area (Includes laundering &amp; casting machine operations)</li> </ul>	<ul style="list-style-type: none"> <li>• As for Furnaces</li> </ul>		<p>TEMCO has conducted TSP monitoring and has characterised the metals in the TSP. This information is likely to be sufficient to characterise emissions for the purposes of NPI reporting.</p>
<p><b>Semi Open Submerged Arc Furnace</b> (Furnace No. 5 at TEMCO)</p> <ul style="list-style-type: none"> <li>• Furnace</li> <li>• Casting and Pouring</li> </ul>	<ul style="list-style-type: none"> <li>• As for sinter plant multicyclone</li> <li>• As for sinter plant conveyers</li> </ul>		<p>See Section 3.2.1 of this Manual</p> <p>No emission estimation techniques presently available<sup>a</sup></p>
<p><b>Vehicle Usage</b></p>	<ul style="list-style-type: none"> <li>• PM<sub>10</sub></li> <li>• Sulfur Dioxide</li> <li>• Carbon Monoxide</li> <li>• Oxides of Nitrogen</li> <li>• Arsenic &amp; Compounds</li> <li>• Cadmium &amp; compounds</li> <li>• Beryllium &amp; compounds</li> <li>• Mercury &amp; compounds</li> <li>• Polycyclic Aromatic Hydrocarbons</li> <li>• Polychlorinated Dioxins and Furans</li> </ul>	<ul style="list-style-type: none"> <li>• Lead &amp; compounds</li> <li>• Manganese &amp; compounds</li> <li>• Nickel &amp; compounds</li> <li>• Zinc &amp; compounds</li> <li>• Cobalt &amp; compounds</li> <li>• Chromium (III) compounds</li> <li>• Chromium (VI) compounds</li> <li>• Copper &amp; compounds</li> <li>• Fluoride compounds</li> </ul>	<p><i>Emission Estimation Technique Manual for Mining</i></p>

<sup>a</sup>Note: A number of industry specific fugitive emissions sources have been identified (from casting and pouring, laundering and casting machine operations). There are no emission estimation techniques currently available for these sources. Our discussions with TEMCO indicate that these emissions are likely to be negligible in the context of overall emissions from the facility. However, there is no measured data to confirm this. It may be that ambient monitoring data can be used in conjunction with site-specific dispersion modelling to enable actual emissions from these sources to be calculated. See the *Emission Estimation Technique Manual for Fugitive Emissions* for a further discussion of this issue. Such studies are, however, beyond the scope of this Manual.

### 3.2.1 Emission Factors for Open Submerged Arc Silicomanganese Furnaces

Table 5 provides emission factors for open submerged arc silicomanganese furnaces. These emission factors are taken from the USEPA (USEPA, 1986) and, in the absence of site-specific data, may be used as a starting point for the estimation of emissions from semi-closed furnaces (such as Furnace No. 5 at TEMCO). Total Suspended Particulates (TSP) data is provided to aid in the calculation of emissions of metal species (see Section 3.2.2). Guidance on the application of emission factors is provided in Appendix A.4 of this Manual.

**Table 5 - Emission Factors for Submerged Arc SiMn Ferroalloy Furnaces<sup>a</sup>**

	PM <sub>10</sub> Mass Emission Factor kg/tonne of alloy produced	TSP Mass Emission Factor kg/tonne of alloy produced
Uncontrolled	92	96
Emission Factor Rating <sup>b</sup>	C	C
With Baghouse <sup>c</sup>	9.2	9.6

<sup>a</sup>USEPA, 1986.

<sup>b</sup>See Appendix B.4 for guidance on the use of emission factor ratings.

<sup>c</sup>Assuming a 90% collection efficiency (*Emission Estimation Technique for Petroleum Refining*).

### 3.2.2 Speciating Total Suspended Particulate Emissions

Under the NPI, particulate emissions are reported as PM<sub>10</sub> emissions. However, to report on metal species present in the particulate matter, total suspended particulate (TSP) data must be used. This section presents a methodology for speciating total suspended particulate emissions.

Emissions of particulate matter will require speciation into individual metal species where reporting thresholds for the metal have been triggered. Equation 1 illustrates the technique for speciating TSP emissions, and Example 2 below shows its application.

#### Equation 1

$$E_{kpy,i} = Q_{TSP} * C_i / 100$$

where:

$$\begin{aligned}
 E_{kpy,i} &= \text{total emissions of TSP species } i, \text{ kg/yr} \\
 Q_{TSP} &= \text{amount of TSP containing species } i \text{ emitted by the facility, kg/yr} \\
 C_i &= \text{concentration of species } i \text{ in TSP, mass \%}
 \end{aligned}$$

Table 6 shows the typical composition of NPI substances in the fume from a semi open submerged arc furnace. They are likely to be other NPI substances present in the fume. However, there are no data presently available on these emissions.

**Table 6 - Weight Percentage Composition of Silicomanganese Fume from a Semi Open Submerged Arc Furnace<sup>a</sup>**

Manganese Concentration Weight %	Manganese Oxide Fume Weight %
17.1	4.7

<sup>a</sup>Chesterman, 1994

### Example 2 - Speciating TSP Emissions

This example demonstrates how speciated TSP emissions from a furnace can be calculated using Equation 1. It is assumed that all TSP is emitted as silicomanganese fume. Approximately 3200 tonnes per annum of fume is produced.

From Table 6, 17.1 % of the fume is Manganese (Mn) so:

$$E_{uc,Mn} = \frac{3200 \text{ tonnes of fume}}{\text{yr}} * \frac{1000 \text{ kg}}{\text{tonne}} * \frac{17.1 \text{ kg Mn}}{100 \text{ kg fume}} = \frac{547.2 \text{ kg Mn}}{\text{yr}}$$

This is an uncontrolled emission rate. The efficiency of the dust collection system should also be taken into account so that:

$$E_{kpy,i} = E_{uc,Mn} * \frac{100 - \text{baghouse efficiency (\%)}}{100}$$

where:

$$\begin{aligned} E_{kpy,i} &= \text{Annual emissions of pollutant, kg/yr} \\ E_{uc,Mn} &= \text{Uncontrolled emission of pollutant, kg/yr} \end{aligned}$$

### 3.3 Emissions to Water

Most of the effluent from the TEMCO facility is routed to the nearby Georgetown Sewage Treatment Plant. This effluent is therefore classed as a transfer under the National Pollutant Inventory.

The one exception to this is stormwater run-off, which is routed through a wetland treatment system. Most of this is recycled to the process although some is released to the environment. TEMCO monitors the wetlands for the following substances:

- Arsenic;
- Cadmium;
- Chromium;
- Copper;
- Fluoride;
- Lead;
- Manganese;
- Mercury; and,
- Zinc.

TEMCO also plans to begin monitoring for cobalt and nickel.



Using this information in conjunction with monitoring data on overflow (release rates) will enable TEMCO to characterise its emissions to water for the purposes of NPI reporting. Example 3 provides an illustration of how monitoring data may be applied to characterise emissions for the purposes of NPI reporting.

### Example 3 - Emissions to Water Calculations

TEMCO releases about 42 m<sup>3</sup>/hr of stormwater into the natural environment (ESS, 1994). A monthly water sample supplied by TEMCO shows a cadmium concentration of 2.1 µg/L. What is the annual emission to water of cadmium based on this sample?

$$\frac{2.1 \text{ } \mu\text{g}}{\text{L}} * \frac{42 \text{ m}^3}{\text{hr}} * \frac{1000 \text{ L}}{\text{m}^3} * \frac{24 \text{ hr}}{\text{d}} * \frac{365 \text{ d}}{\text{y}} * \frac{1 \text{ t}}{1 * 10^{12} \text{ } \mu\text{g}} = \frac{7.7 * 10^{-4} \text{ t}}{\text{y}}$$

Therefore, based on this example, 7.7 \* 10<sup>-4</sup> tonnes per year or 0.77 kg per year of cadmium is emitted to water through stormwater run-off. Note that this assumes a continuous regular discharge, whereas, in practice, the actual stormwater discharge is much more variable than this.

## 3.4 Emissions to Land

Under the NPI, the following are classed as transfers and are not required to be reported:

- Discharges of substances to sewer or tailings dam;
- Deposit of substances to landfill; and,
- Removal of substances from a facility for destruction, treatment, recycling, reprocessing, recovery, or purification.

The definition of transfer has been clarified by the NPI Implementation Working Group as:

“All emissions of listed substances, except those which are directed to, and contained by, purpose built facilities, are to be reported to the NPI. This applies irrespective of whether the substances’ fate is within or outside a reporting facility boundary. With respect to receipt of NPI-listed substances, such receiving facilities are to be operating in accordance with any applicable State or Territory government requirements.”

TEMCO is currently establishing a comprehensive groundwater-monitoring program for the facility. It is intended that the results of this monitoring will enable TEMCO to characterise the contribution of the facility, if any, to the pollutant levels in the local groundwater.

In terms of meeting NPI reporting requirements, this approach is reasonable in situations where there is no loss of substances (eg. due to evaporation) prior to the substance entering the groundwater, and where the time between the release occurring, and the

---

substance entering the groundwater is minimal. Therefore, for those facilities where groundwater monitoring captures all releases to land, such monitoring can be used as a reasonable measure of emissions to the environment. If this is not the case (eg. where the rate of transmission through the soil/clay is low, or where there are other routes whereby substances to land are carried off-site, such as evaporation or surface run-off); a more detailed investigation would be required. This would be a highly site-specific issue.

TEMCO produces a range of liquid and solid wastes. The major waste streams are:

- Materials collected in dust collection and other pollution control equipment;
- Silicomanganese slag; and
- Tar.

From discussions with TEMCO, the disposal routes of each of these wastes are such that all of these wastes are classed as transfers and, hence, are not required to be reported.

---

## 4.0 Glossary of Technical Terms and Abbreviations

ANZSIC	Australian and New Zealand Standard Industrial Classification
CEMS	Continuous Emission Monitoring System
CO	Carbon monoxide
EEA	European Environment Agency
EET	Emission Estimation Technique
EFR	Emission Factor Rating
Mn	Manganese
NEPM	National Environment Protection Measure
NO <sub>x</sub>	Oxides of nitrogen
NPI	National Pollutant Inventory
PM	Particulate Matter
PM <sub>10</sub>	Particulate matter with an equivalent aerodynamic diameter of 10 micrometres or less (ie. ≤10µm)
SO <sub>2</sub>	Sulfur dioxide
Transfer	Transfers consist of a deposit of a substance into landfill, or discharge of a substance to a sewer or tailings dam, or removal of a substance from a facility for destruction, treatment, recycling, reprocessing, recovery or purification. Emissions classed as transfers are not required to be reported under the NPI.
TSP	Total Suspended Particulates
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compounds

---

## 5.0 References

ANZSIC, 1993, *Australian and New Zealand Standard Industrial Classification*, Australian Bureau of Statistics & NZ Dept of Statistics, Canberra, Australia.

Chesterman, B., 1994, *Tasmanian Electro Metallurgical Company Pty Ltd - Bell Bay Tasmania - Environmental Management Plan No. 2*, Environmental Scientific Services (ESS), Australia.

Perry, R. and Green, D., 1997, *Perry's Chemical Engineers' Handbook*, 7<sup>th</sup> Ed., McGraw-Hill, New York, USA.

USEPA, October, 1986. *Emission Factor Documentation for AP-42, Section 12.4, Ferroalloy Production*, United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.

<http://www.epa.gov/ttn/chief/ap42pdf/c12s04.pdf>

The following EET Manuals are available at the NPI Homepage:

(<http://www.npi.gov.au>)

*Emission Estimation Technique Manual for Combustion in Boilers;*

*Emission Estimation Technique Manual for Fugitive Emissions;*

*Emission Estimation Technique Manual for Mining; and*

*Emission Estimation Technique Manual for Petroleum Refining.*

These Manuals are also available from your State or Territory environmental protection authority.

---

## Appendix A - Emission Estimation Techniques

Estimates of emissions of NPI-listed substances to air, water and land should be reported for each substance that triggers a threshold. The reporting list and detailed information on thresholds are contained in the 'NPI Guide' at the front of this Handbook.

In general, there are four types of emission estimation techniques (EETs) that may be used to estimate emissions from your facility.

The four types described in the 'NPI Guide' are:

- Sampling or direct measurement;
- Mass balance;
- Fuel analysis or other engineering calculations; and
- Emission factors.

Select the EETs (or mix of EETs) that is most appropriate for your purposes. For example, you might choose to use a mass balance to best estimate fugitive losses from pumps and vents, direct measurement for stack and pipe emissions, and emission factors when estimating losses from storage tanks and stockpiles.

If you estimate your emission by using any of these EETs, your data will be displayed on the NPI database as being of 'acceptable reliability'. Similarly, if your relevant environmental authority has approved the use of EETs that are not outlined in this handbook, your data will also be displayed as being of 'acceptable reliability'.

This Manual seeks to provide the most effective emission estimation techniques for the NPI substances relevant to this industry. However, the absence of an EET for a substance in this handbook does not necessarily imply that an emission should not be reported to the NPI. The obligation to report on all relevant emissions remains if reporting thresholds have been exceeded.

**You are able to use emission estimation techniques that are not outlined in this document. You must, however, seek the consent of your relevant environmental authority. For example, if your company has developed site-specific emission factors, you may use these if approved by your relevant environmental authority.**

You should note that the EETs presented or referenced in this Manual relate principally to average process emissions. Emissions resulting from non-routine events are rarely discussed in the literature, and there is a general lack of EETs for such events. However, it is important to recognise that emissions resulting from significant operating excursions and/or accidental situations (eg. spills) will also need to be estimated. Emissions to land, air and water from spills must be estimated and added to process emissions when calculating total emissions for reporting purposes. The emission resulting from a spill is the net emission, ie. the quantity of the NPI reportable substance spilled, less the quantity recovered or consumed during clean up operations.

A list of the variables and symbols used in this Manual may be found in Appendix C.

---

## A.1 Direct Measurement

You may wish to undertake direct measurement in order to report to the NPI, particularly if you already do so in order to meet other regulatory requirements. However, the NPI does not require you to undertake additional sampling and measurement. For the sampling data to be adequate and able to be used for NPI reporting purposes, it would need to be collected over a period of time, and to be representative of operations for the whole year.

### A.1.1 Sampling Data

Stack sampling test reports often provide emissions data in terms of kg per hour or grams per cubic metre (dry). Annual emissions for NPI reporting can be calculated from this data. Stack tests for NPI reporting should be performed under representative (ie. normal) operating conditions. You should be aware that some tests undertaken for a State or Territory license condition may require the test be taken under maximum emissions rating, where emissions are likely to be higher than when operating under normal operating conditions.

An example of test results is summarised in Table 7. The table shows the results of three different sampling runs conducted during one test event. The source parameters measured as part of the test run include gas velocity and moisture content, which are used to determine exhaust gas flow rates in m<sup>3</sup>/s. The filter weight gain is determined gravimetrically and divided by the volume of gas sampled, as shown in Equation 2 to determine the PM concentration in grams per m<sup>3</sup>. Note that this example does not present the condensable PM emissions.

Pollutant concentration is then multiplied by the volumetric flow rate to determine the emission rate in kilograms per hour, as shown in Equation 3 and Example 4.

#### Equation 2

$$C_{PM} = C_f / V_{m,STP}$$

where:

$$\begin{aligned} C_{PM} &= \text{concentration of PM or gram loading, g/m}^3 \\ C_f &= \text{filter catch, g} \\ V_{m,STP} &= \text{metered volume of sample at STP, m}^3 \end{aligned}$$

#### Equation 3

$$E_{PM} = C_{PM} * Q_d * 3.6 * [273 / (273 + T)]$$

where:

$$\begin{aligned} E_{PM} &= \text{hourly emissions of PM, kg/hr} \\ C_{PM} &= \text{concentration of PM or gram loading, g/m}^3 \\ Q_d &= \text{stack gas volumetric flow rate, m}^3/\text{s, dry} \\ 3.6 &= \text{3600 seconds per hour multiplied by 0.001 kilograms per gram} \\ T &= \text{temperature of the gas sample, } ^\circ\text{C} \end{aligned}$$

**Table 7 - Stack Sample Test Results**

Parameter	Symbol	Test 1	Test 2	Test 3
Total sampling time (sec)		7200	7200	7200
Moisture collected (g)	$g_{\text{MOIST}}$	395.6	372.6	341.4
Filter catch (g)	$C_f$	0.0851	0.0449	0.0625
Average sampling rate (m <sup>3</sup> /s)		$1.67 * 10^{-4}$	$1.67 * 10^{-4}$	$1.67 * 10^{-4}$
Standard metered volume (m <sup>3</sup> )	$V_{\text{m,STP}}$	1.185	1.160	1.163
Volumetric flow rate (m <sup>3</sup> /s), dry	$Q_d$	8.48	8.43	8.45
Concentration of particulate (g/m <sup>3</sup> )	$C_{\text{PM}}$	0.0718	0.0387	0.0537

**Example 4 - Using Stack Sampling Data**

PM emissions calculated using Equation 2 and Equation 3 (above) and the stack sampling data for Test 1 (presented in Table 7, and an exhaust gas temperature of 150°C (423 K)). This is shown below:

$$\begin{aligned}
 C_{\text{PM}} &= C_f / V_{\text{m,STP}} \\
 &= 0.0851 / 1.185 \\
 &= 0.072 \text{ g/m}^3 \\
 \\ 
 E_{\text{PM}} &= C_{\text{PM}} * Q_d * 3.6 * [273 / (273 + T)] \\
 &= 0.072 * 8.48 * 3.6 * (273 / 423 \text{ K}) \\
 &= 1.42 \text{ kg/hr}
 \end{aligned}$$

The information from some stack tests may be reported in grams of particulate per cubic metre of exhaust gas (wet). Use Equation 4 below to calculate the dry particulate emissions in kg/hr.

**Equation 4**

$$E_{\text{PM}} = Q_a * C_{\text{PM}} * 3.6 * (1 - \text{moist}_r / 100) * [273 / (273 + T)]$$

where:

- $E_{\text{PM}}$  = hourly emissions of PM in kilograms per hour, kg/hr
- $Q_a$  = actual (ie. wet) cubic metres of exhaust gas per second, m<sup>3</sup>/s
- $C_{\text{PM}}$  = concentration of PM or gram loading, g/m<sup>3</sup>
- 3.6 = 3600 seconds per hour multiplied by 0.001 kilograms per gram
- $\text{moist}_r$  = moisture content, %
- 273 = 273 K (0°C)
- T = stack gas temperature, °C

Total suspended particulates (TSP) are also referred to as total particulate matter (total PM). To determine PM<sub>10</sub> from total PM emissions, a size analysis may need to be undertaken. The weight PM<sub>10</sub> fraction can then be multiplied by the total PM emission rate to produce PM<sub>10</sub> emissions. Alternatively, it can be assumed that 100% of PM emissions are PM<sub>10</sub> (ie. assume that all particulate matter emitted to air has an equivalent aerodynamic diameter of 10 micrometres or less ie. ≤10µm). In most situations, this is likely to be a conservative assumption but may be sufficient to obtain a reasonable characterisation of emissions for the purposes of NPI reporting.

To calculate moisture content use Equation 5.

### Equation 5

Moisture percentage = 100 % \* weight of water vapour per specific volume of stack gas/ total weight of the stack gas in that volume.

$$moist_R = \frac{100\% * \left( \frac{g_{moist}}{1000 * V_{m,STP}} \right)}{\left( \frac{g_{moist}}{1000 * V_{m,STP}} \right) + \rho_{STP}}$$

where:

moist<sub>R</sub> = moisture content, %  
 g<sub>moist</sub> = moisture collected, g  
 V<sub>m,STP</sub> = metered volume of sample at STP, m<sup>3</sup>  
 ρ<sub>STP</sub> = dry density of stack gas sample, kg/m<sup>3</sup> at STP  
 (if the density is not known a default value of 1.62 kg/m<sup>3</sup> may be used. This assumes a dry gas composition of 50% air, 50% CO<sub>2</sub>)

### Example 5 - Calculating Moisture Percentage

A 1.2m<sup>3</sup> sample (at STP) of gas contains 410g of water. To calculate the moisture percentage use Equation 5.

$$moist_R = \frac{100\% * \left( \frac{g_{moist}}{1000 * V_{m,STP}} \right)}{\left( \frac{g_{moist}}{1000 * V_{m,STP}} \right) + \rho_{STP}}$$

$$\begin{aligned} g_{MOIST} / 1000 * V_{m,STP} &= 410 / (1000 * 1.2) \\ &= 0.342 \\ moist_R &= 100 * 0.342 / (0.342 + 1.62) \\ &= 17.4\% \end{aligned}$$



### A.1.2 Continuous Emission Monitoring System (CEMS) Data

A continuous emission monitoring system (CEMS) provides a continuous record of emissions over time, usually by reporting pollutant concentration. Once the pollutant concentration is known, emission rates are obtained by multiplying the pollutant concentration by the volumetric gas or liquid flow rate of that pollutant.

Although CEMS can report real-time hourly emissions automatically, it may be necessary to estimate annual emissions from hourly concentration data Manually. This Section describes how to calculate emissions for the NPI from CEMS concentration data. The selected CEMS data should be representative of operating conditions. When possible, data collected over longer periods should be used.

It is important to note that, prior to using CEMS to estimate emissions, you should develop a protocol for collecting and averaging the data in order that the estimate satisfies the local environmental authority's requirement for NPI emission estimations.

To monitor SO<sub>2</sub>, NO<sub>x</sub>, VOC, and CO emissions using a CEMS, you use a pollutant concentration monitor that measures the concentration in parts per million by volume dry air (ppm<sub>vd</sub> = volume of pollutant gas/10<sup>6</sup> volumes of dry air). Flow rates should be measured using a volumetric flow rate monitor. Flow rates estimated based on heat input using fuel factors may be inaccurate because these systems typically run with high excess air to remove the moisture out of the kiln. Emission rates (kg/hr) are then calculated by multiplying the stack gas concentrations by the stack gas flow rates.

Table 8 presents example CEMS data output for three periods for a hypothetical furnace. The output includes pollutant concentrations in parts per million dry basis (ppm<sub>vd</sub>), diluent (O<sub>2</sub> or CO<sub>2</sub>) concentrations in percent by volume dry basis (%v, d) and gas flow rates; and may include emission rates in kilograms per hour (kg/hr). This data represents a snapshot of a hypothetical boiler operation. While it is possible to determine total emissions of an individual pollutant over a given time period from this data, assuming the CEMS operates properly all year long, an accurate emission estimate can be made by adding the hourly emission estimates if the CEMS data is representative of typical operating conditions.

**Table 8 - Example CEMS Output for a Hypothetical Furnace Firing Waste Fuel Oil**

Time	O <sub>2</sub> content	Concentration				Gas Flow Rate (Q)	Production Rate of Product (A)
		SO <sub>2</sub> (ppm <sub>vd</sub> )	NO <sub>x</sub> (ppm <sub>vd</sub> )	CO (ppm <sub>vd</sub> )	VOC (ppm <sub>vd</sub> )		
	% by volume					m <sup>3</sup> /s	tonnes/hour
1	10.3	150.9	142.9	42.9	554.2	8.52	290
2	10.1	144.0	145.7	41.8	582.9	8.48	293
3	11.8	123.0	112.7	128.4	515.1	8.85	270

Hourly emissions can be based on concentration measurements as shown in Equation 6

---

**Equation 6**

$$E_i = (C * MW * Q * 3600) / [22.4 * (T + 273/273) * 10^6]$$

where:

$E_i$	=	emissions of pollutant i, kg/hr
$C$	=	pollutant concentration, ppm <sub>v,d</sub>
$MW$	=	molecular weight of the pollutant, kg/kg-mole
$Q$	=	stack gas volumetric flow rate, m <sup>3</sup> /s
$3600$	=	conversion factor, s/hr
$22.4$	=	volume occupied by one mole of gas at standard temperature and pressure (0°C and 101.3 kPa), m <sup>3</sup> /kg-mole
$T$	=	temperature of gas sample, °C

Actual annual emissions can be calculated by multiplying the emission rate in kg/hr by the number of actual operating hours per year (OpHrs) as shown in Equation 7 for each typical time period and summing the results.

**Equation 7**

$$E_{kpy,i} = \sum (E_i * OpHrs)$$

where:

$E_{kpy,i}$	=	annual emissions of pollutant i, kg/yr
$E_i$	=	emissions of pollutant i, kg/hr (from Equation 6)
$OpHrs$	=	operating hours, hr/yr

Emissions in kilograms of pollutant per tonne of product produced can be calculated by dividing the emission rate in kg/hr by the activity rate (production rate (tonnes/hr) during the same period. This is shown in Equation 8 below.

It should be noted that the emission factor calculated below assumes that the selected time period (ie. hourly) is representative of annual operating conditions and longer time periods should be used for NPI reporting where they are available. Use of the calculation is shown in Example 6.

**Equation 8**

$$E_{kpt,i} = E_i / A$$

where:

$E_{kpt,i}$	=	emissions of pollutant i per tonne of product produced, kg/t
$E_i$	=	hourly emissions of pollutant i, kg/hr
$A$	=	clinker production, t/hr

Example 6 illustrates the application of Equation 6, Equation 7 and Equation 8.

### Example 6 - Using CEMS Data

This example shows how SO<sub>2</sub> emissions can be calculated using Equation 6 based on the CEMS data for Time Period 1 shown in Table 8, and an exhaust gas temperature of 150°C (423 K).

$$\begin{aligned} E_{\text{SO}_2,1} &= (C * MW * Q * 3600) / [(22.4 * (T + 273/273) * 10^6)] \\ &= (150.9 * 64 * 8.52 * 3600) / [22.4 * (423/273) * 10^6] \\ &= 296\,217\,907 / 34\,707\,692 \\ &= 8.53 \text{ kg/hr} \end{aligned}$$

For Time Period 2, also at 150°C

$$E_{\text{SO}_2,2} = 8.11 \text{ kg/hr}$$

For Time Period 3, also at 150°C

$$E_{\text{SO}_2,3} = 7.23 \text{ kg/hr}$$

Say representative operating conditions for the year are:

$$\begin{aligned} \text{Period 1} &= 1500 \text{ hr} \\ \text{Period 2} &= 2000 \text{ hr} \\ \text{Period 3} &= 1800 \text{ hr} \end{aligned}$$

Total emissions for the year are calculated by adding the results of the three Time Periods using Equation 7:

$$\begin{aligned} E_{\text{kpy,SO}_2} &= E_{\text{SO}_2,1} * \text{OpHrs} + E_{\text{SO}_2,2} * \text{OpHrs} + E_{\text{SO}_2,3} * \text{OpHrs} \\ &= (8.53 * 1500) + (8.11 * 2000) + (7.23 * 1800) \text{ kg} \\ &= 42\,021 \text{ kg/yr} \end{aligned}$$

Emissions, in terms of kg/tonne of product produced when operating in the same mode as time period 1, can be calculated using Equation 8:

$$\begin{aligned} E_{\text{kpt,SO}_2} &= E_{\text{SO}_2} / A \\ &= 8.53 / 290 \\ &= 2.94 * 10^{-2} \text{ kg SO}_2 \text{ emitted per tonne of product produced} \end{aligned}$$

When the furnace is operating as in time periods 2 or 3, similar calculations can be undertaken for emissions per tonne.

## A.2 Using Mass Balance

A mass balance identifies the quantity of substance going in and out of an entire facility, process, or piece of equipment. Emissions can be calculated as the difference between input and output of each listed substance. Accumulation or depletion of the substance within the equipment should be accounted for in your calculation.

Mass balance calculations for estimating emissions to air of NPI-listed substances can be represented conceptually by Equation 9.

#### Equation 9

$$E_{kpy,i} = \text{Amount in}_i - \text{Amount out}_i$$

where:

$$\begin{aligned} E_{kpy,i} &= \text{emissions of pollutant } i, \text{ kg/yr} \\ \text{Amount in}_i &= \text{amount of pollutant } i \text{ entering the process, kg/yr} \\ \text{Amount out}_i &= \text{amount of pollutant } i \text{ leaving the process as a waste stream, article or product, kg/yr} \end{aligned}$$

The term “Amount out<sub>i</sub>” may actually involve several different fates for an individual pollutant. This could include the amount recovered or recycled, the amount leaving the process in the manufactured product, the amount leaving the process in wastewater, the amount emitted to the atmosphere, or the amount of material transferred off-site as hazardous waste or to landfill. A thorough knowledge of the different fates for the pollutant of interest is necessary for an accurate emission estimate to be made using the mass balance approach.

The amount of a particular substance entering or leaving a facility is often mixed within a solution as a formulation component or as a trace element within the raw material. To determine the total weight of the substance entering or leaving the process, the concentration of the substance within the material is required. Using this concentration data, Equation 10 can be applied as a practical extension of Equation 9.

#### Equation 10

$$E_{kpy,i} = [(Q_{in} * C_{in}) - (Q_{pr} * C_{pr}) - (Q_{rec} * C_{rec}) - (Q_{waste} * C_{waste})] / 10^6$$

where:

$$\begin{aligned} E_{kpy,i} &= \text{emissions of pollutant } i, \text{ kg/yr} \\ Q_{in}, Q_{pr}, Q_{rec}, Q_{waste} &= \text{quantity of raw material, product, recycled material or waste respectively, that is processed (generally expressed in kg for solids, L for liquids)} \\ C_{in}, C_{pr}, C_{rec}, C_{waste} &= \text{concentration of substance } i \text{ in the raw material, product, recycled material or waste respectively, that is processed annually (usually mg/kg for solids, mg/L for liquids)} \\ 10^6 &= \text{conversion from milligrams to kilograms.} \end{aligned}$$

Wastewater treatment may precipitate the reportable chemical in a sludge. Facilities are often required to obtain data on the concentration of metals or other substances in sludges as part of their licensing requirement and this data can be used to calculate the emissions as kilograms of sludge multiplied by the concentrations of the substance in the sludge. Although listed substances in sludges transferred off-site do not require reporting, determining this loss can assist with determining other process losses or may require reporting if the sludge is disposed of on-site.

---

For many chemicals used and emitted during chemical processes, some degradation in treatment may occur so that the entire chemical is not transferred to the sludge. Facilities can estimate the amount of reportable compounds in the sludge by using measured data, or by subtracting the amount biodegraded from the total amount removed in treatment. The amount of removal can be determined from operating data, and the extent of biodegradation might be obtained from published studies. If the biodegradability of the chemical cannot be measured or is not known, reporting facilities should assume that all removal is due to absorption to sludge.

### A.3 Engineering Calculations

An engineering calculation is an estimation method based on physical/chemical properties (eg. vapour pressure) of the substance and mathematical relationships (eg. ideal gas law).

#### A.3.1 Fuel Analysis

Fuel analysis is an example of an engineering calculation and can be used to predict SO<sub>2</sub>, metals, and other emissions based on application of conservation laws, if fuel rate is measured. The presence of certain elements in fuels may be used to predict their presence in emission streams. This includes elements such as sulfur that may be converted into other compounds during the combustion process.

The basic equation used in fuel analysis emission calculations is the following:

#### Equation 11

$$E_{kpy,i} = Q_f * C_i / 100 * (MW_p / EW_f) * OpHrs$$

where:

$E_{kpy,i}$	=	annual emissions of pollutant i, kg/yr
$Q_f$	=	fuel use, kg/hr
OpHr	=	operating hours, hr/yr
$MW_p$	=	molecular weight of pollutant emitted, kg/kg-mole
$EW_f$	=	elemental weight of pollutant in fuel, kg/kg-mole
$C_i$	=	concentration of pollutant i in fuel, weight percent, %

For instance, SO<sub>2</sub> emissions from fuel oil combustion can be calculated based on the concentration of sulfur in the fuel oil. This approach assumes complete conversion of sulfur to SO<sub>2</sub>. Therefore, for every kilogram of sulfur (EW = 32) burned, two kilograms of SO<sub>2</sub> (MW = 64) are emitted. The application of this EET is shown in Example 7.

### Example 7 - Using Fuel Analysis Data

This example shows how SO<sub>2</sub> emissions can be calculated from fuel combustion based on fuel analysis results, and the known fuel flow of the engine. E<sub>kpy,SO<sub>2</sub></sub> may be calculated using Equation 11 and given the following:

Fuel flow (Q<sub>f</sub>) = 20 900 kg/hr  
Weight percent sulfur in fuel = 1.17 %  
Operating hours = 1500 hr/yr

$$\begin{aligned} E_{\text{kpy,SO}_2} &= Q_f * C_i / 100 * (MW_p / EW_p) * \text{OpHrs} \\ &= (20\,900) * (1.17 / 100) * (64 / 32) * 1500 \\ &= 733\,590 \text{ kg/yr} \end{aligned}$$

### A.4 Emission Factors

In the absence of other information, default emission factors can be used to provide an estimate of emissions. Emission factors are generally derived through the testing of a general source population (eg. boilers using a particular fuel type). This information is used to relate the quantity of material emitted to some general measure of the scale of activity (eg. for boilers, emission factors are generally based on the quantity of fuel consumed or the heat output of the boiler).

Emission factors require 'activity data', that is combined with the factor to generate the emission estimates. The generic formula is:

#### Equation 12

$$\text{Emission Factor} \left( \frac{\text{mass}}{\text{unit of activity}} \right) * \text{Activity Data} \left( \frac{\text{unit of activity}}{\text{time}} \right) = \text{Emission Rate} \left( \frac{\text{mass}}{\text{time}} \right)$$

For example, if the emission factor has units of '*kg pollutant/m<sup>3</sup> of fuel combusted*', then the activity data required would be in terms of '*m<sup>3</sup> fuel burned/hr*', thereby generating an emission estimate of '*kg pollutant/hr*'.

An emission factor is a tool used to estimate emissions to the environment. In this Manual, it relates the quantity of substances emitted from a source, to some common activity associated with those emissions. Emission factors are obtained from US, European, and Australian sources and are usually expressed as the weight of a substance emitted, divided by the unit weight, volume, distance, or duration of the activity emitting the substance.

---

Emission factors are used to estimate a facility's emissions by the general equation:

**Equation 13**

$$E_{kpy,i} = [A * OpHrs] * EF_i * [1 - (CE_i/100)]$$

where:

- $E_{kpy,i}$  = emission rate of pollutant i, kg/yr
- $A$  = activity rate, t/hr
- $OpHrs$  = operating hours, hr/yr
- $EF_i$  = uncontrolled emission factor of pollutant i, kg/t
- $CE_i$  = overall control efficiency of pollutant i, %.

Emission factors developed from measurements for a specific process may sometimes be used to estimate emissions at other sites. Should a company have several processes of similar operation and size, and emissions are measured from one process source, an emission factor can be developed and applied to similar sources. It is necessary to have the site-specific emission factor reviewed and approved by State or Territory environment agencies prior to its use for NPI estimations.

---

## Appendix B - Emission Estimation Techniques: Acceptable Reliability and Uncertainty

This section is intended to give a general overview of some of the inaccuracies associated with each of the techniques. Although the National Pollutant Inventory does not favour one emission estimation technique over another, this section does attempt to evaluate the available emission estimation techniques with regards to accuracy.

Several techniques are available for calculating emissions from ferroalloy facilities. The technique chosen is dependent on available data, and available resources, and the degree of accuracy sought by the facility in undertaking the estimate. In general, site-specific data that is representative of normal operations is more accurate than industry-averaged data, such as the emission factors discussed in Appendix A.4 of this Manual.

### B.1 Direct Measurement

Use of stack and/or workplace health and safety sampling data is likely to be a relatively accurate method of estimating air emissions from ferroalloy facilities. However, collection and analysis of samples from facilities can be very expensive and especially complicated where a variety of NPI-listed substances are emitted, and where most of these emissions are fugitive in nature. Sampling data from a specific process may not be representative of the entire manufacturing operation, and may provide only one example of the facility's emissions.

To be representative, sampling data used for NPI reporting purposes needs to be collected over a period of time, and to cover all aspects of production.

In the case of CEMS, instrument calibration drift can be problematic and uncaptured data can create long-term incomplete data sets. However, it may be misleading to assert that a snapshot (stack sampling) can better predict long-term emission characteristics. It is the responsibility of the facility operator to properly calibrate and maintain monitoring equipment and the corresponding emissions data.

### B.2 Mass Balance

Calculating emissions from ferroalloy facilities using mass balance appears to be a straightforward approach to emission estimation. However, it is likely that few Australian facilities consistently track material usage and waste generation with the overall accuracy needed for application of this method. Inaccuracies associated with individual material tracking, or other activities inherent in each material handling stage, can result in large deviations for total facility emissions. Because emissions from specific materials are typically below 2 percent of gross consumption, an error of only  $\pm 5$  percent in any one step of the operation can significantly skew emission estimations.



---

### B.3 Engineering Calculations

Theoretical and complex equations, or models, can be used for estimating emissions from ferroalloy production processes. EET equations are available for the following types of emissions common to ferroalloy facilities.

Use of emission equations to estimate emissions from ferroalloy facilities is a more complex and time-consuming process than the use of emission factors. Emission equations require more detailed inputs than the use of emission factors but they do provide an emission estimate that is based on facility-specific conditions

### B.4 Emission Factors

Every emission factor has an associated emission factor rating (EFR) code. This rating system is common to EETs for all industries and sectors and therefore, to all Industry Handbooks. They are based on rating systems developed by the United States Environmental Protection Agency (USEPA), and by the European Environment Agency (EEA). Consequently, the ratings may not be directly relevant to Australian industry. Sources for all emission factors cited can be found in the reference section of this document. The emission factor ratings will not form part of the public NPI database.

When using emission factors, you should be aware of the associated EFR code and what that rating implies. An A or B rating indicates a greater degree of certainty than a D or E rating. The less certainty, the more likely that a given emission factor for a specific source or Category is not representative of the source type. These ratings notwithstanding, the main criterion affecting the uncertainty of an emission factor remains the degree of similarity between the equipment/process selected in applying the factor, and the target equipment/process from which the factor was derived.

The EFR system is as follows:

A	-	Excellent
B	-	Above Average
C	-	Average
D	-	Below Average
E	-	Poor
U	-	Unrated

## Appendix C - List of Variables and Symbols

Variable	Symbol	Units
Annual emissions of pollutant i	$E_{kpyi}$	kg/yr
Total emissions of pollutant i per hour	$E_i$	kg/hr
Uncontrolled emission factor for pollutant i	$EF_i$	kg of pollutant/unit of weight, volume, distance or duration of activity emitting the pollutant
Overall control efficiency	$CE_i$	% reduction in emissions of pollutant i
Fuel used	$Q_f$	kg/hr
Concentration of pollutant i	$C_i$	ppmv, kg/L
Total suspended particulates in exhaust gases or air	TSP	kg/hr
Operating hours	OpHrs	hr/yr
Activity rate	A	t/hr
Molecular weight of pollutant emitted	$MW_i$	kg/kg-mole
Elemental weight of pollutant in fuel	$EW_f$	kg/kg-mole
Concentration of substance i in the raw material, product, recycled material or waste respectively, that is processed annually	$C_{in}$ $C_{pr}$ $C_{rec}$	kg/kg, kg/L
Quantity of raw material, product, recycled material or waste respectively, that is processed annually	$Q_{in}$ $Q_{pr}$ $Q_{rec}$	Generally expressed in kg/yr for solids, L/yr for liquids
Concentration of PM or gram loading	$C_{PM}$	$g/m^3$
Filter Catch	$C_f$	g
Metered volume of sample at STP	$V_{mSTP}$	$m^3$
Hourly emissions of PM	$E_{PM}$	kg/hr
Stack gas volumetric flowrate	$Q_{st}$	$m^3/s$
Temperature	T	°Celsius (°C) or Kelvin (K)
Moisture collected	$g_{moist}$	g
Moisture content	$moist_R$	%
Dry density of stack gas sample at STP	$\rho_{STP}$	$kg/m^3$
Emissions per tonne	$E_{kpt,i}$	kg of pollutant i per tonne of fuel consumed
Amount of TSP containing species i emitted by the facility	$Q_{TSP}$	kg/yr